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A TECHNIQUE FOR RECORDING A NOISE-FREE ELECTROCARDIOGRAM FROM A CHICKEN EMBRYO STILL IN ITS SHELL

1. INTRODUCTION

Two recent developments at Ames Research Center, a new miniature biopotential telemetry system (FRYER and DEBOO, 1964) and an ultra-sensitive momentum transducer (ROGALLO, 1964), have been combined to enable one to use the momentum pulses from chick embryo heartbeats to study the ECG under conditions where previously such study was impossible.

Embryo electrocardiology, although by no means exhaustively investigated up to now, has been studied more (ROMANOFF, 1960) and is better understood than embryo ballistocardiology, owing to the newness of the latter. However, the use of the momentum transducer as a ballistocardiograph (BCG) makes it possible to obtain reliable ECG waveform information under adverse conditions of signal-to-noise ratio.

Many investigations in the biological sciences involve the measurement of small electrical signals, which are, to a greater or lesser degree, masked by noise. Methods have been developed by which it is possible to extract a waveform from the noise (CLARK, 1958; CLYNES, 1961; LEDLEY, 1962), even though the noise may be considerably greater than the signal. These techniques involve electronically summing repetitious signals and computing their

The temporal relationship between the ECG and the BCG is indicated in Fig. 2. It has been found that the repetition period, T_1, and the time relationship between the ECG and the BCG, T_2, are both extremely constant over a period of minutes, with the egg held at a constant temperature. Consequently, a prominent spike in the BCG waveform can be used as a trigger for the computer.

2. EXPERIMENTAL PROCEDURE

Figure 3 is a block diagram showing the equipment setup, and Fig. 4 is a photograph of the ballistocardiograph with the egg mounted on it.

A dental burr was used to remove two small areas of shell about one-tenth of an inch in diameter from a 10-day egg, and a silver-silver chloride wire was inserted into each hole. Care was taken not to break the underlying membrane; see Fig. 5. Radio telemetry of the ECG was found to be desirable because any wires attached to the egg and to equipment not on the BCG isolation platform picked up mechanical vibrations and caused considerable mechanically induced noise on the highly sensitive BCG channel.

The main requirements for the telemetry system are, low equivalent input noise, high input impedance, small size, and low weight. The telemetry system used has an equivalent input noise level of about 5 microvolts peak-to-peak over a bandwidth of 0.5 to 40 cps and an input impedance of 20 megohms. It is 0.74 inch in diameter by 0.20 inch thick and weighs 2 grams, which is suitably small compared with the size and weight of a 50-gram chicken egg.

The egg and telemetry transmitter were placed on the BCG instrument, which was mounted on a mechanical isolation system inside an incubator. The receiving antenna for the ECG telemetry system was simply a length of wire looped around the incubator. The output of the receiving system was fed to the input of the average-response computer.

The BCG signal (amplified, filtered, rectified, and wave-shaped by means of conventional circuits) triggered the average-response computer, which was run with an analysis period of 0.5 sec for about 1 minute.

Figures 6(a) and 6(b) show the unprocessed ECG. Figure 6(a) shows the unprocessed ECG with compressed time scale, illustrating the lack of observable periodicity. Figure 6(b) shows a segment of the ECG with the same time scale as for the average-computed ECG record.

Figure 6(c) shows the computer-processed version of the ECG waveform, and figure 6(d) shows the BCG waveform used to trigger the computer.

3. DISCUSSION

Comparison of Figs. 6(a) and 6(b) with 6(c) indicates that the processed ECG can reveal waveform information which is not at all apparent from direct observation of the unprocessed version. The excellent repetition in the two wave-form complexes in Fig. 6(c) confirms that both the heart rate and the time relationship between the ECG and BCG are sufficiently constant to enable the BCG to be used as a trigger for average-response computing of the ECG.

Further work could be done to study the effects of electrode placement on the ECG waveform. If the standard ECG paste used in this experiment were replaced by some other type of less irritating, slower drying paste, long term studies on embryo ECG's would be possible.

The BCG has been detected in chick embryos as young as 4 days old, and it is thus possible that clean ECG waveforms might also be detected from embryos appreciably younger than the 10-day embryo of this test.

SUMMARY

A noise-free electrocardiogram (ECG) has been recorded from a chicken embryo by means of an average-response computer, even though the ECG signal-to-noise ratio was so low that no consistent signal suitable for triggering the computer was available.

To measure the ECG, small areas of shell were removed from two locations on the egg, care being taken not to damage the underlying membrane, and electrodes were attached to these areas.

The required trigger was provided by a recently developed, highly sensitive ballistocardiograph.

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FIGURE TITLES

Fig. 1.- Avian ballistocardiograph sensing mechanism.

Fig. 2.- Temporal relationship between ECG and BCG.

Fig. 3.- Block diagram of setup.

Fig. 4.- Photograph of ECG telemeter and ballistocardiograph.

Fig. 5.- Method of contact for ECG electrodes.

Fig. 6.- Photographs of waveforms obtained. (a) Unprocessed ECG, compressed time scale. Horizontal: 0.2 sec/cm. Vertical: 20 microvolts/cm. (b) Unprocessed ECG, expanded time scale. Horizontal: 0.05 sec/cm. Vertical: 20 microvolts/cm. (c) Processed ECG. Horizontal: 0.05 sec/cm. Vertical: 5 microvolts/cm. (d) BCG trigger. Horizontal: 0.05 sec/cm. Vertical: 150 microvolts/cm.

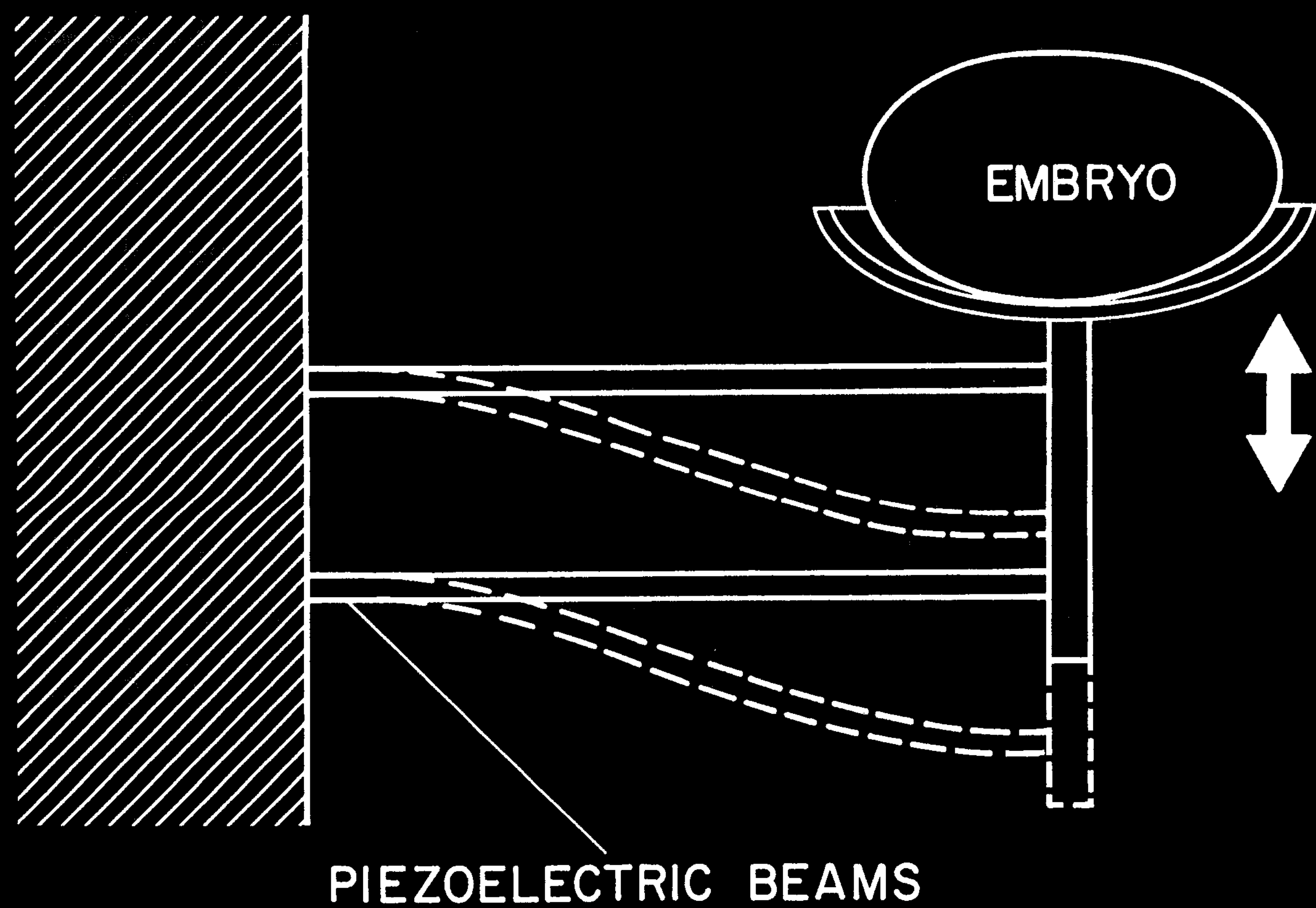

Fig. 1.- Avian ballistocardiograph sensing mechanism.

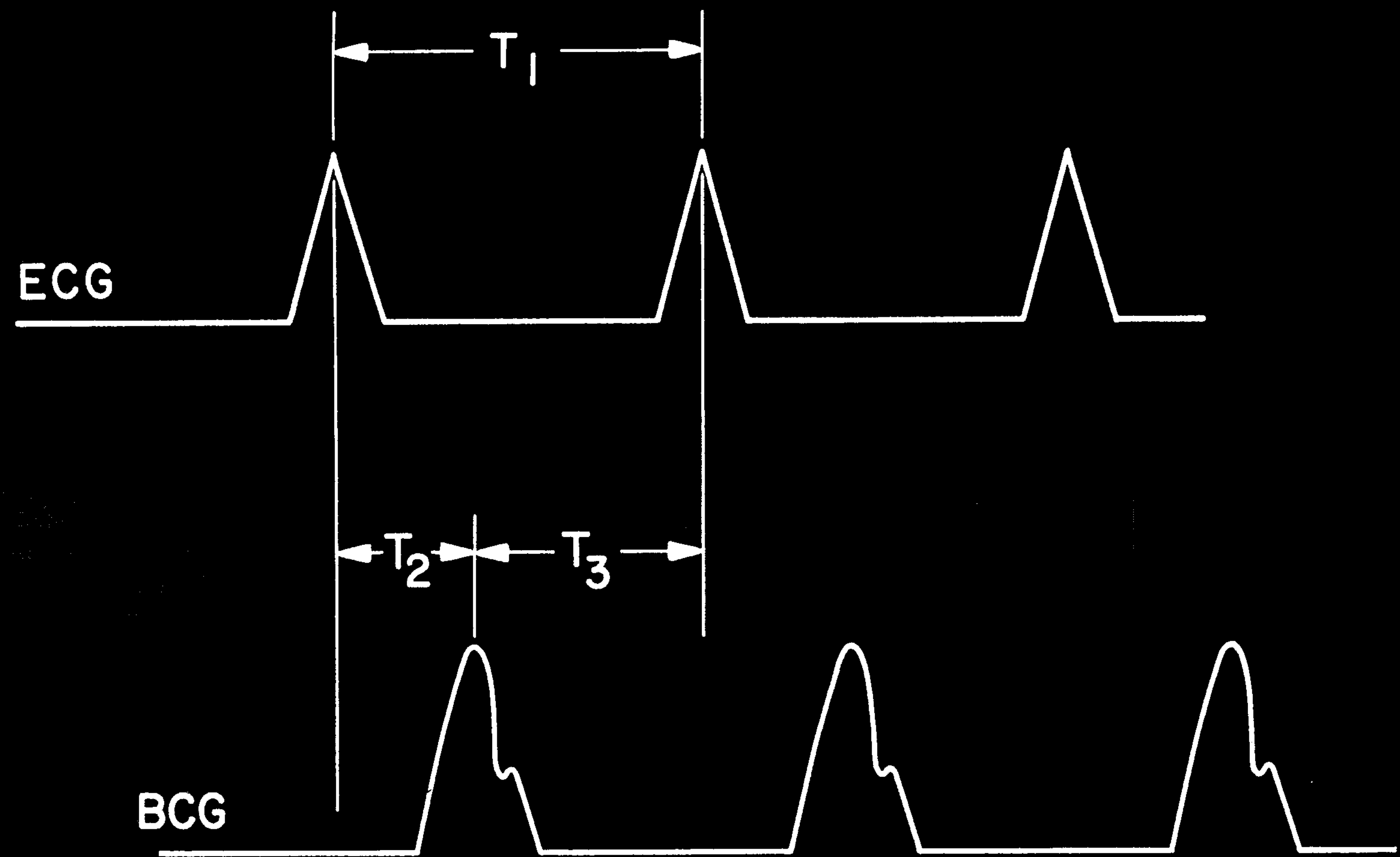

Fig. 2.- Temporal relationship between ECG and BCG.

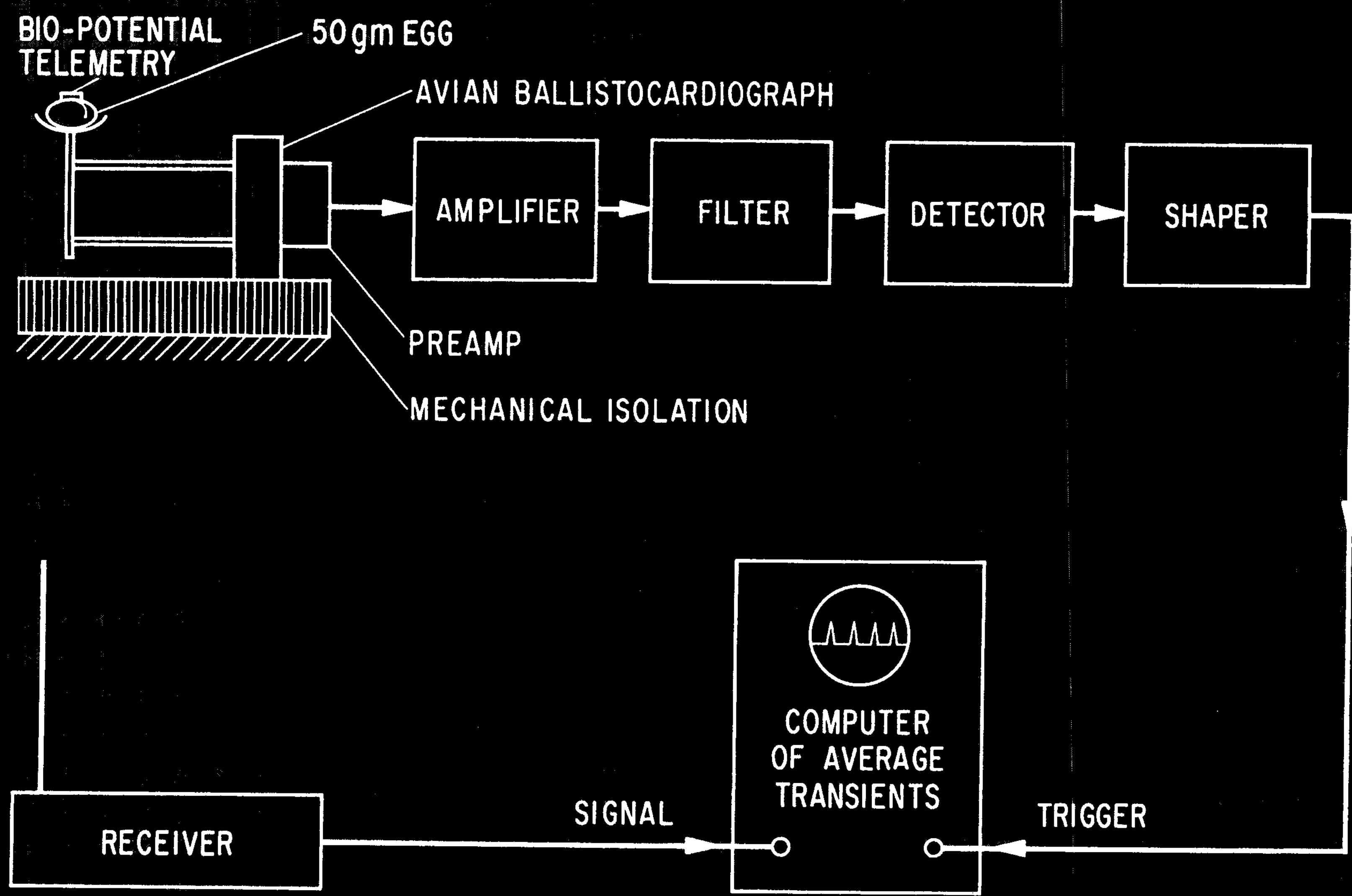

Fig. 3.- Block diagram of setup.

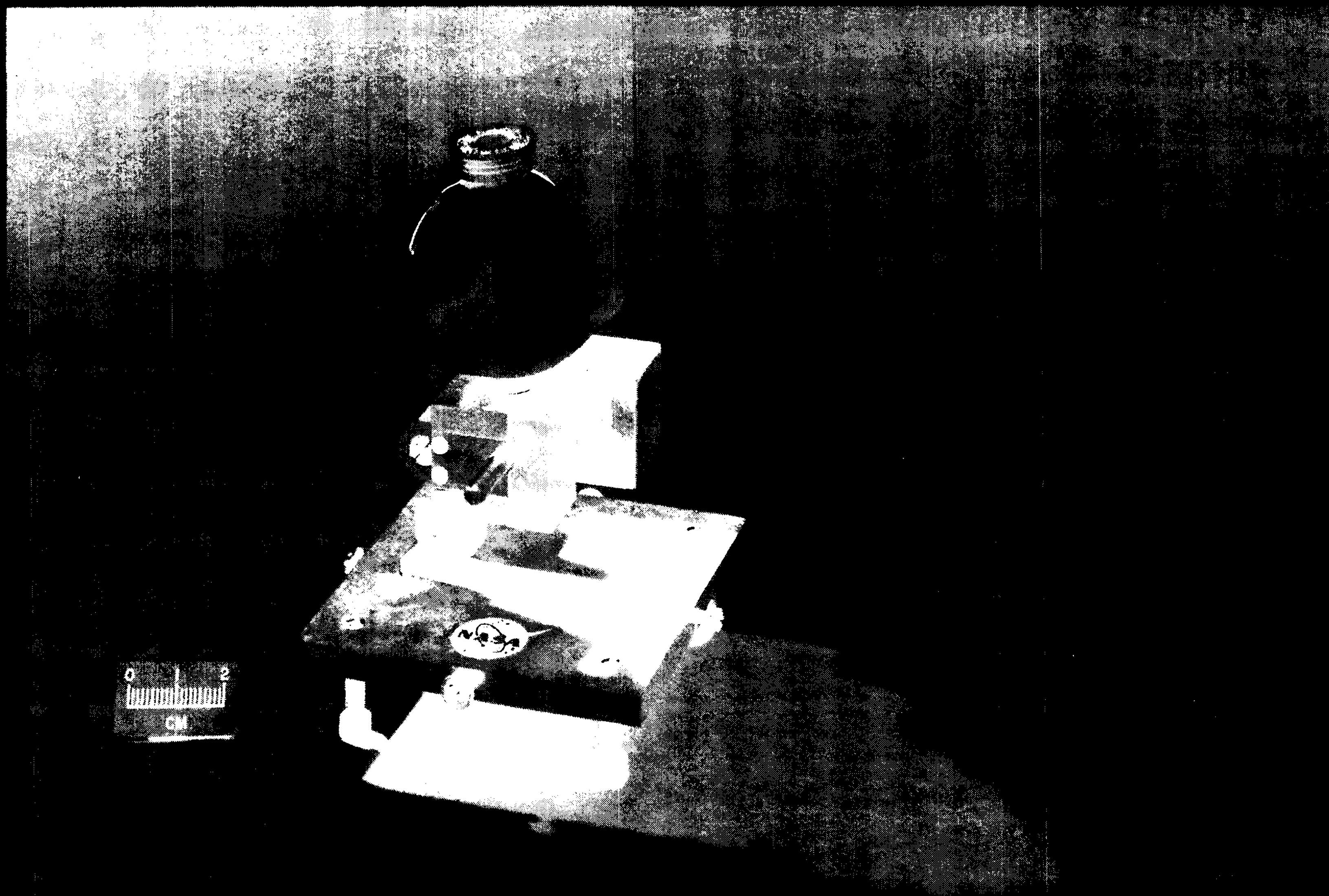

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Fig. 4.- Photograph of ECG telemeter and ballistocardiograph.

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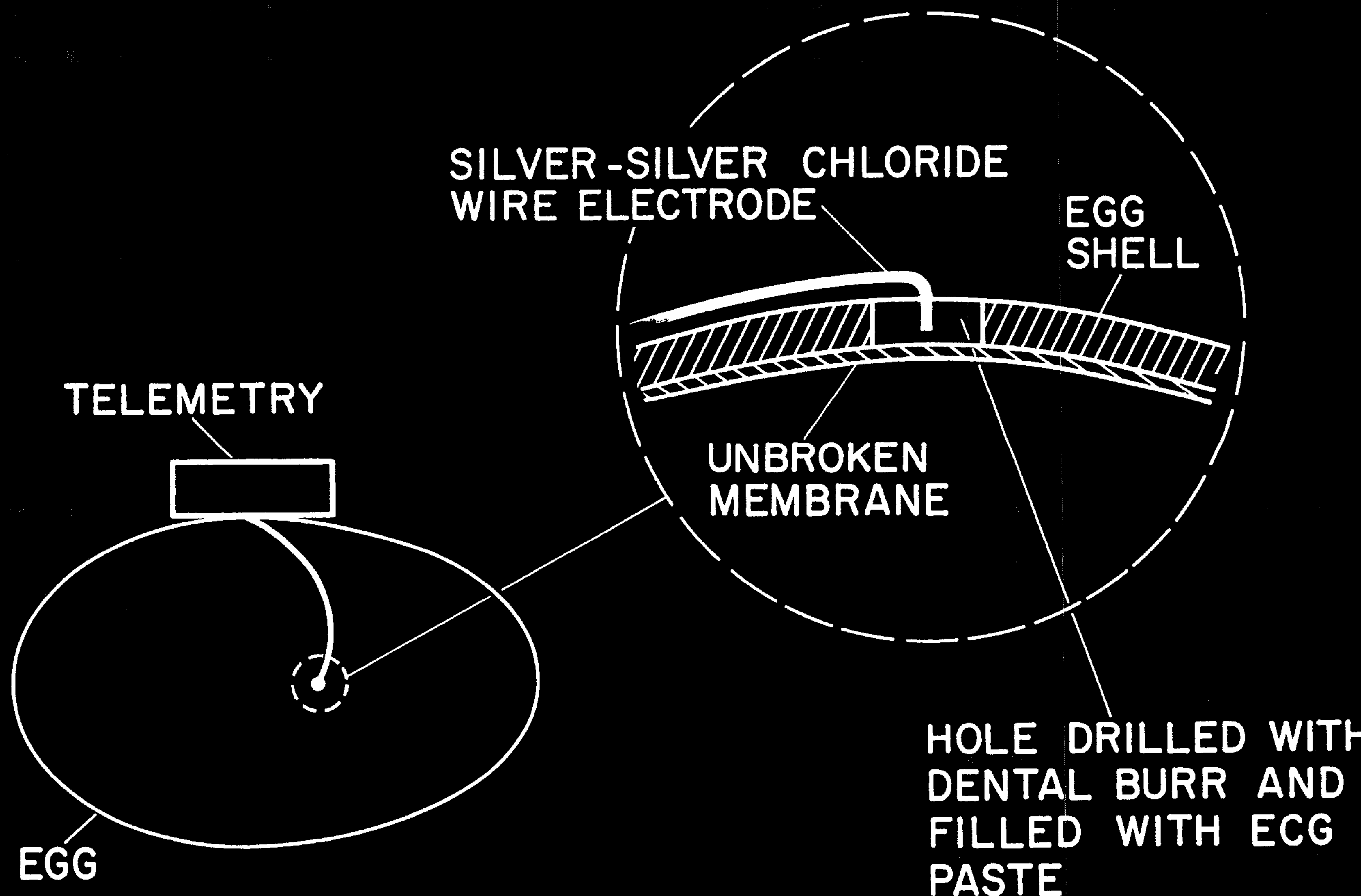

Fig. 5.- Method of contact for ECG electrodes.

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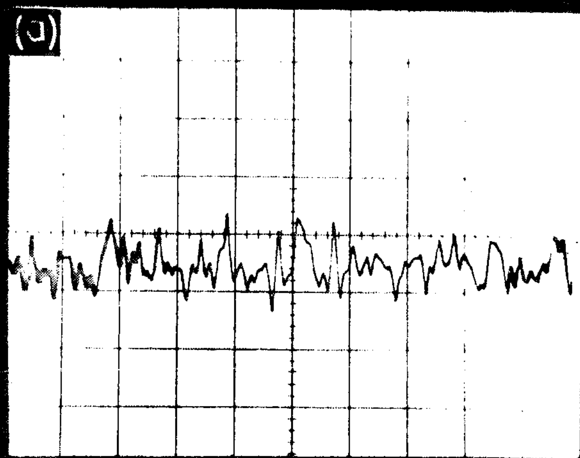
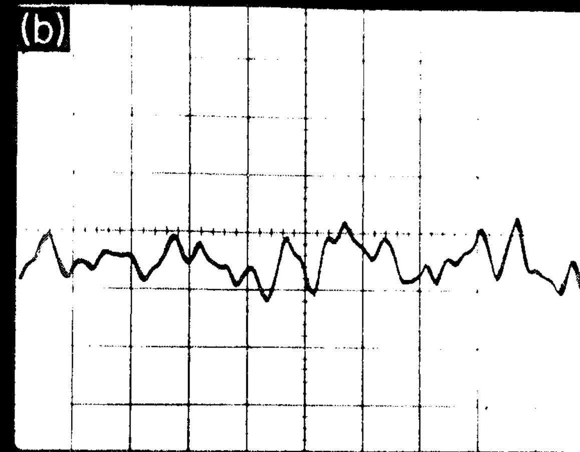
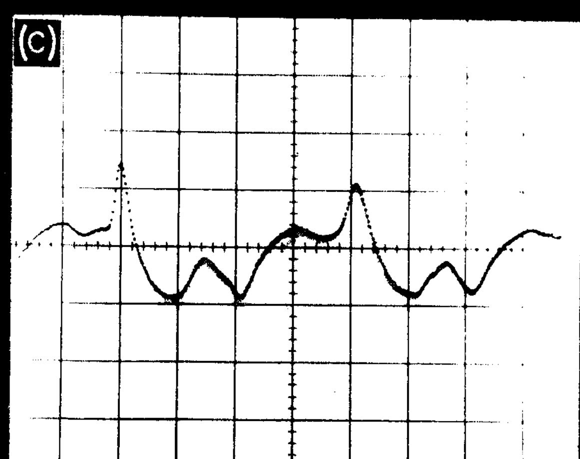


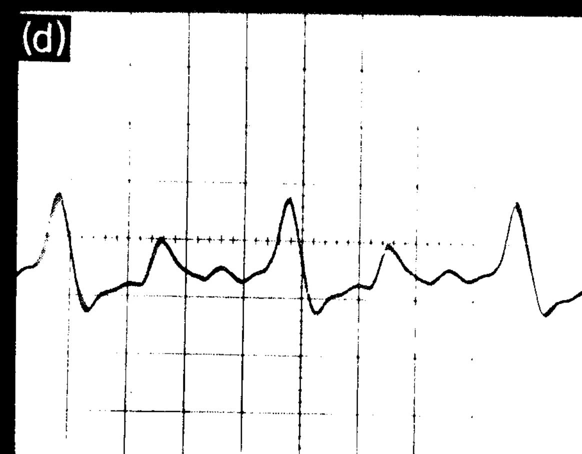
(a) Unprocessed ECG, compressed time scale.
Horizontal: 0.2 sec/cm
Vertical: 20 microvolts/cm



(b) Unprocessed ECG, expanded time scale.
Horizontal: 0.05 sec/cm
Vertical: 20 microvolts/cm



(c) Processed ECG.
Horizontal: 0.05 sec/cm
Vertical: 5 microvolts/cm



(d) BCG trigger.
Horizontal: 0.05 sec/cm
Vertical: 150 microvolts/cm

Fig. 6.- Photographs of waveforms obtained.

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